New Developments in Secondary Emission Calorimeters

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CPAD Instrumentation Frontier Meeting

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Secondary Emission Calorimeters

- Intrinsically Radiation Hard
  - Secondary emission is radiation hard
  - No photocathode, no light transport
- Intrinsically Fast (~1ns signal formation)
  - Time scale from secondary emission process
  - No extra time scales from atomic decays (eg. scintillation)
- **Both features are a huge plus for future colliders which require increased instantaneous luminosity**

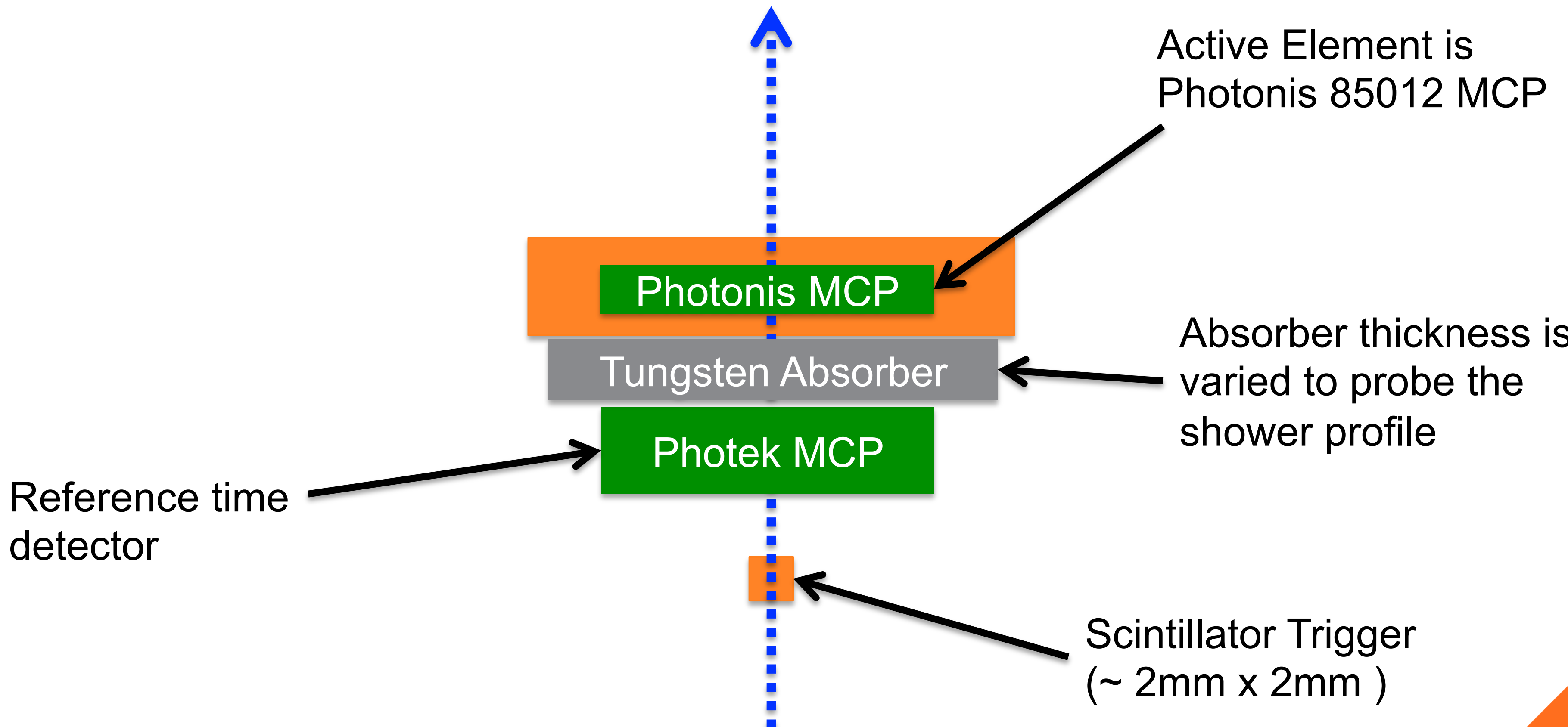
I will describe work done with Fermilab (A. Ronzhin, S. Los) and Caltech (A. Apresyan, C. Pena, F. Presutti, M. Spiropulu) collaborators.

Additional Capabilities

- We investigated extra capabilities of secondary emission calorimeters with important implications for future detectors:
  - Electromagnetic Shower Position
  - Precision Timing

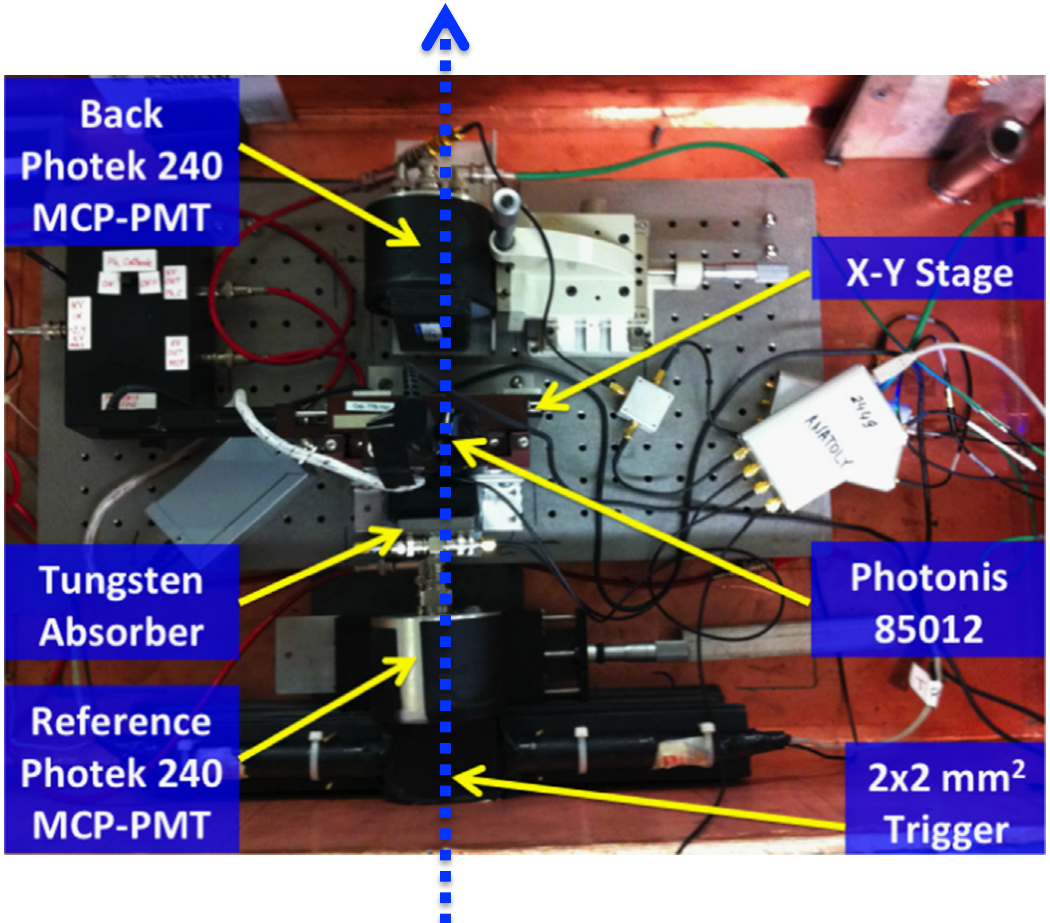
- These aspects are studied with a secondary emission calorimeter using multi-channel plates (MCP) as the active element

MCP as active element of a shower max detector

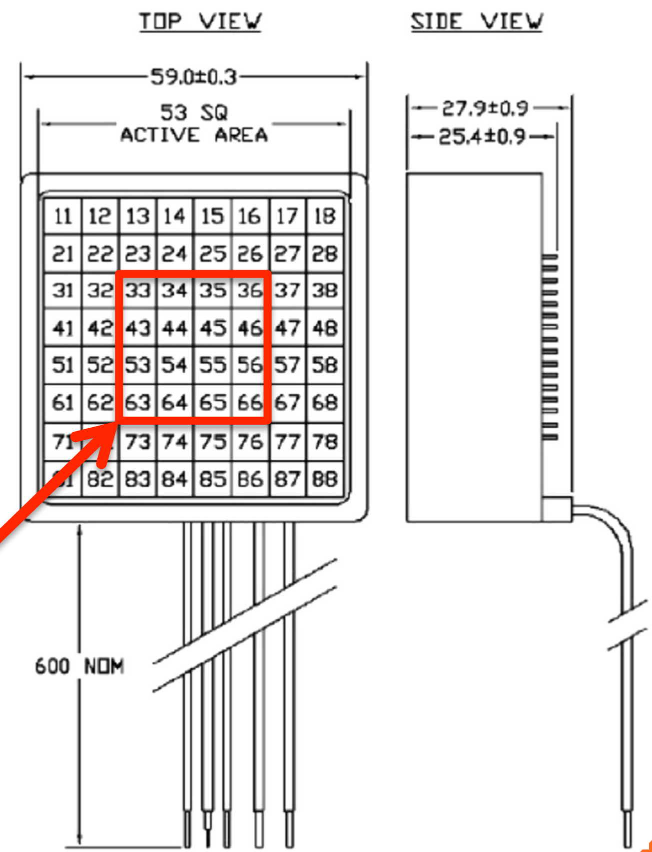


Electron Beam @
Fermilab Testbeam Facility

MCP as active element of a shower max detector



Photonis XP85012 MCP

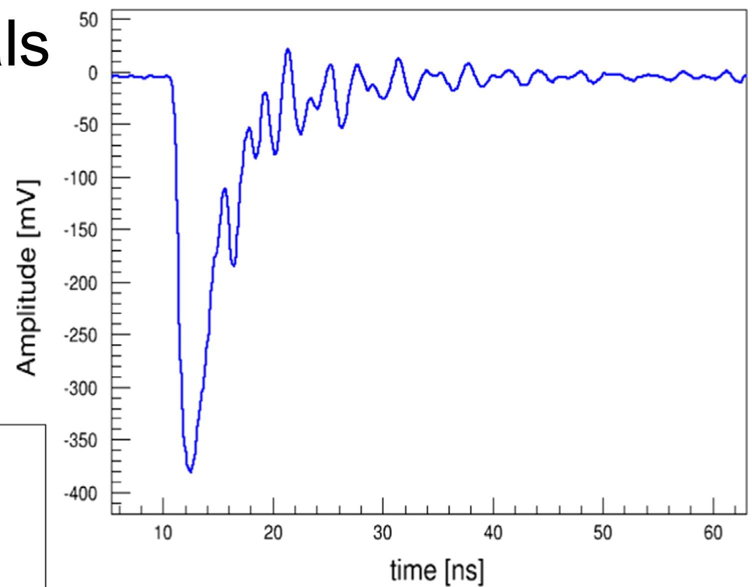


- Pixelated anodes of size: 6mmx6mm
- Central 4x4 pixels ganged together and read out as a single channel

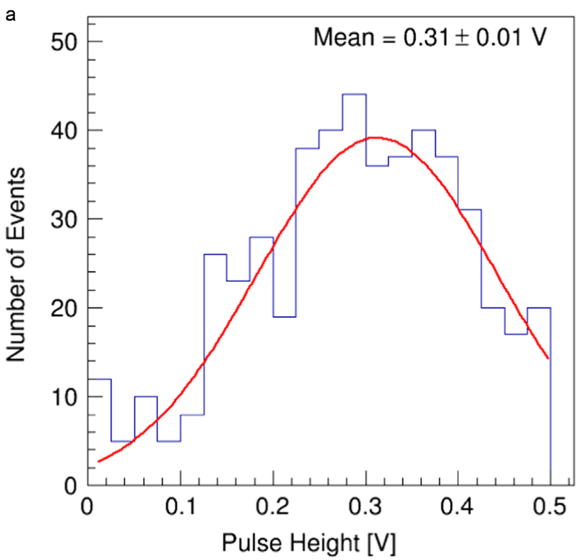
Pure secondary emission signals

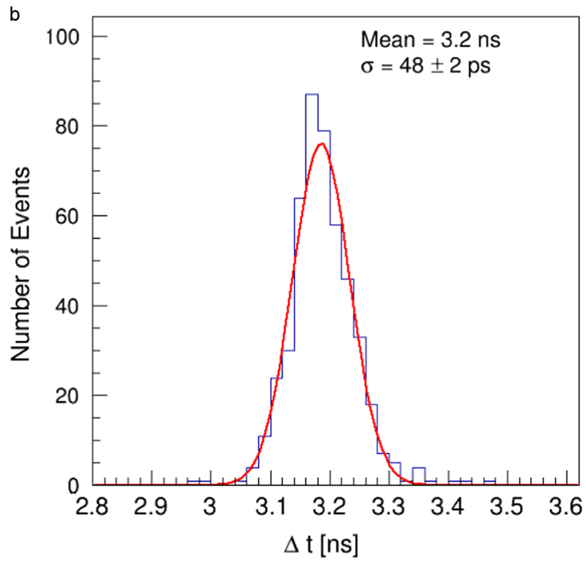
Examples of secondary emission signals

- 8 GeV electron beam
- 4 X_0 of tungsten absorber



Amplitude Distribution

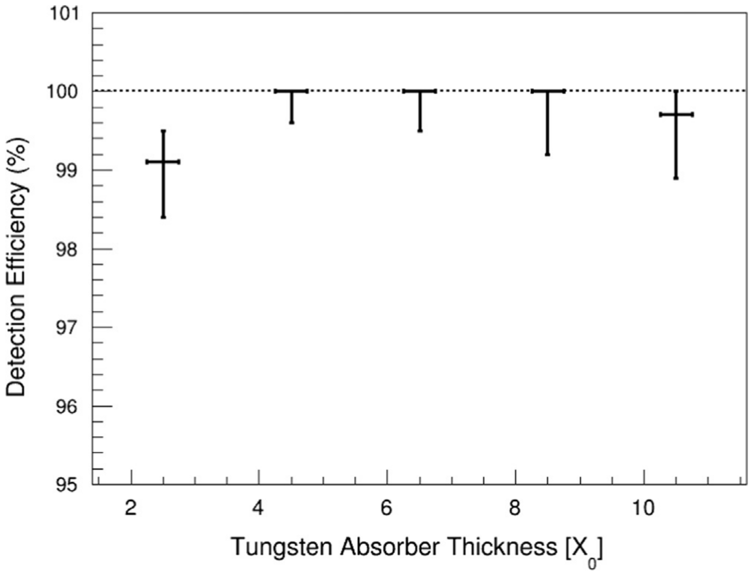




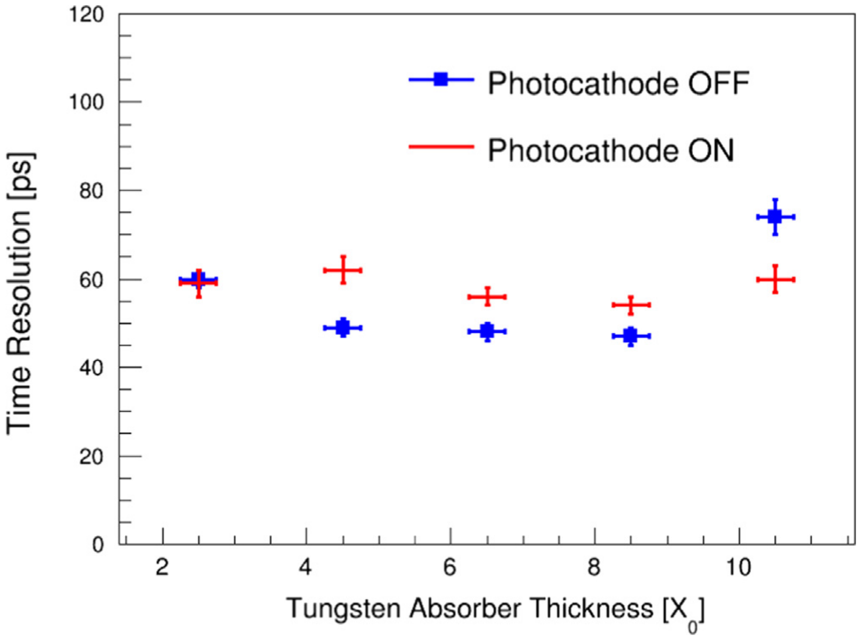
Time of Flight wrt ref detector

Performance

Detection Efficiency



Time resolution measurement



- Achieve ~100% detection efficiency for EM showers
- Achieve ~50ps time resolution everywhere in the EM shower

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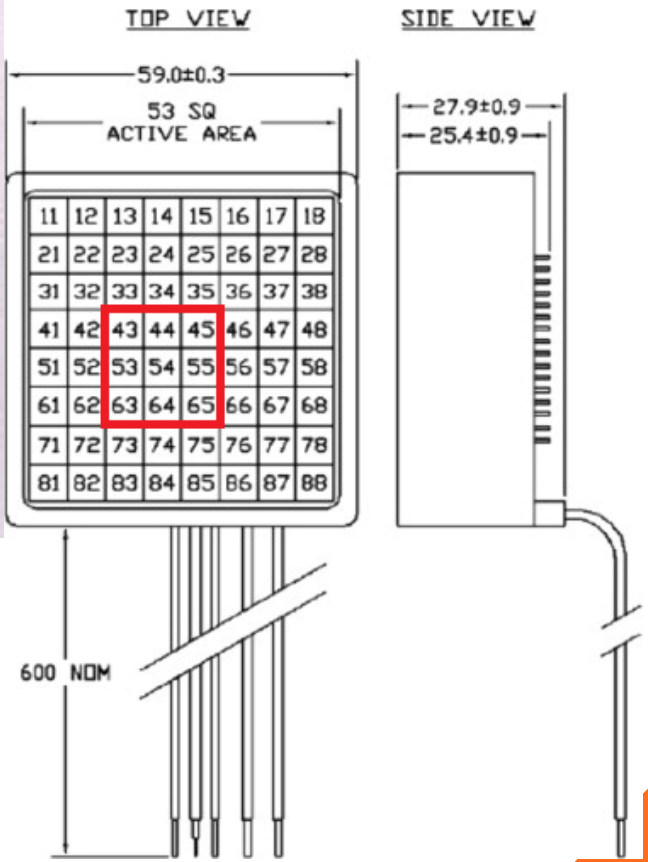
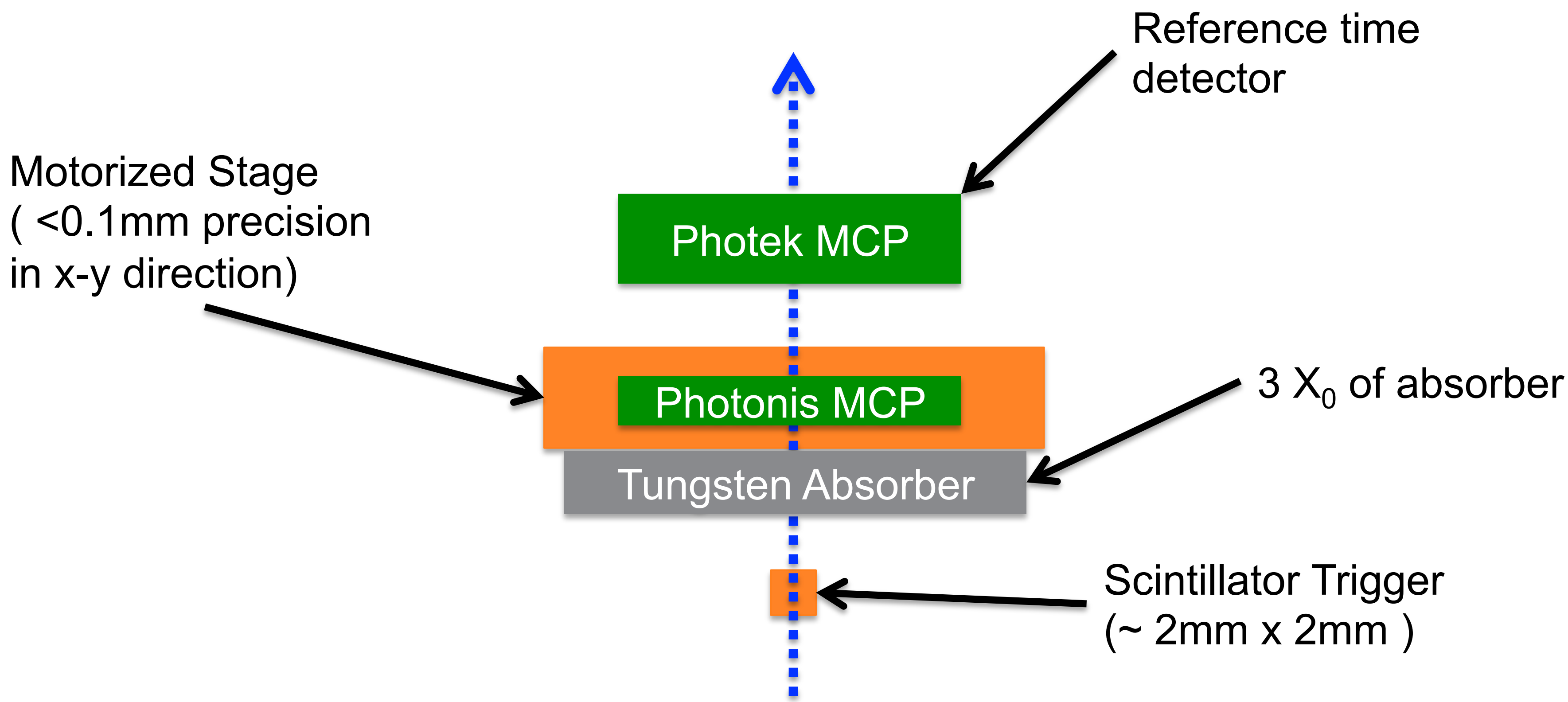
Shower Position Studies with Pixelated Readout



Each 6mm x 6mm pixel read out as separate channels

Testbeam Setup



Electron Beam @
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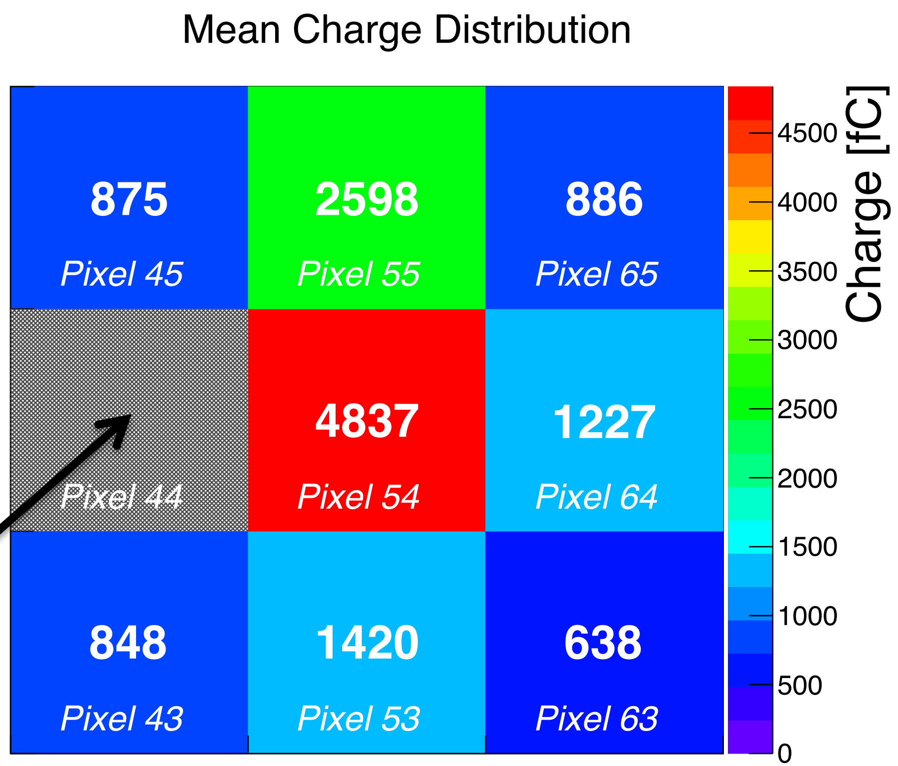
Shower Position Reconstruction

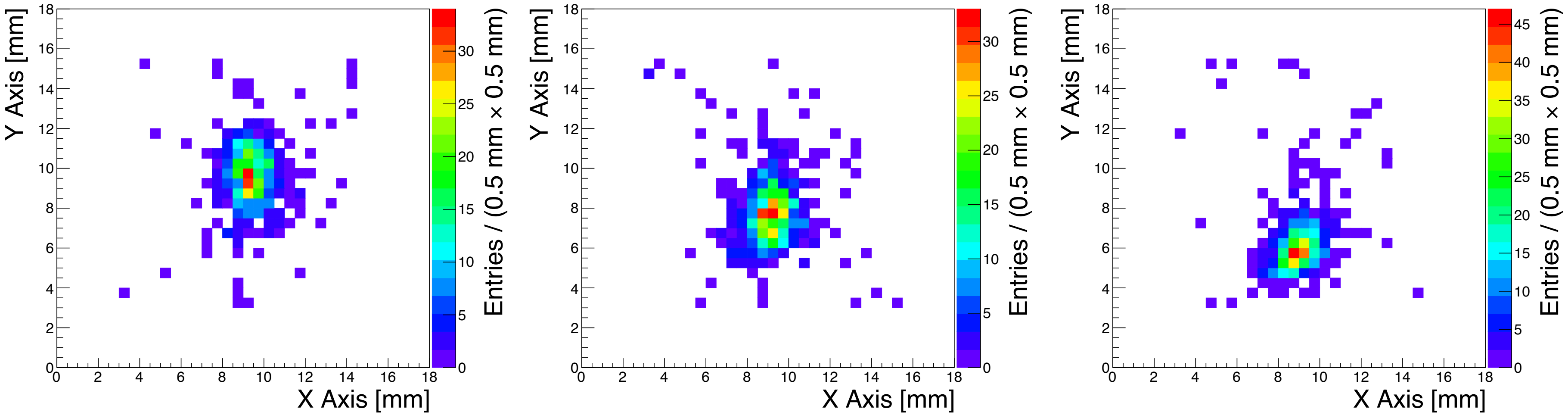
Use a simple energy-weighted position reconstruction

$$\vec{\mathbf{p}} = \frac{\sum_{i \in \mathrm{pixels}} Q_i \vec{p_i}}{\sum_{i \in \mathrm{pixels}} Q_i}$$

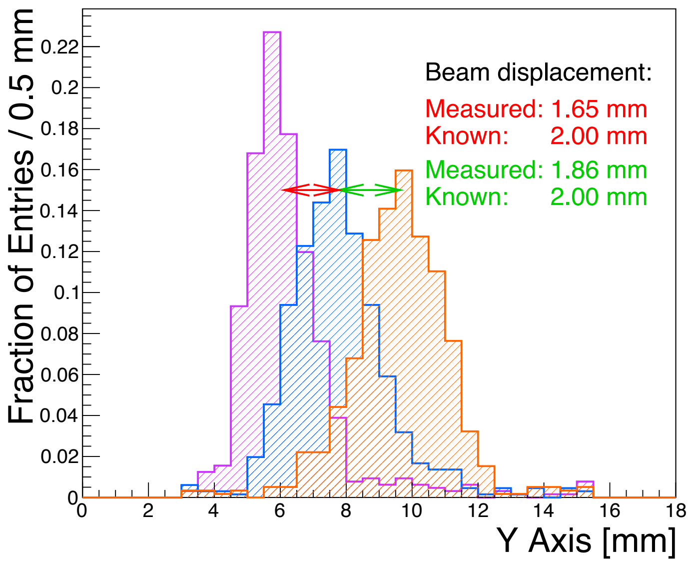


Unfortunately 1 pixel turned out to be dead

Three example beam positions



We observe shower positions are well reconstructed on average



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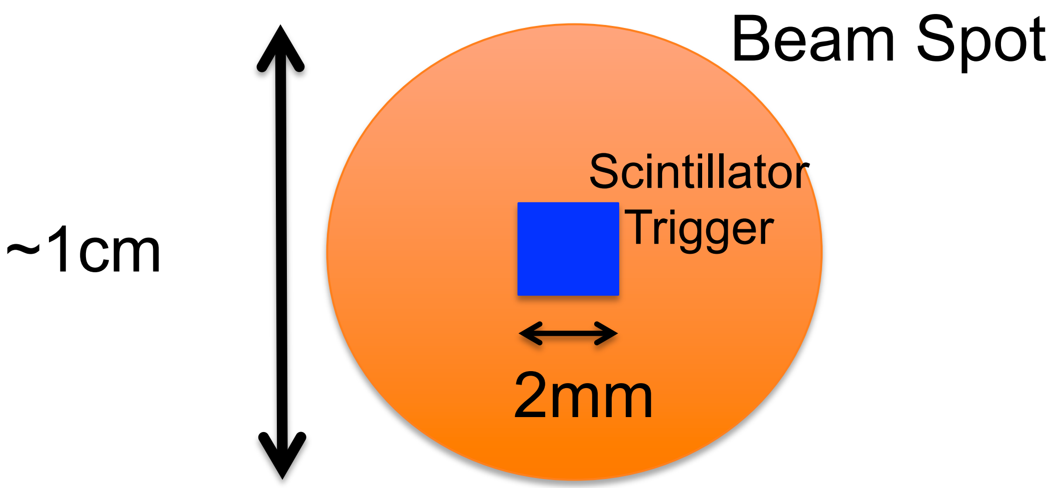
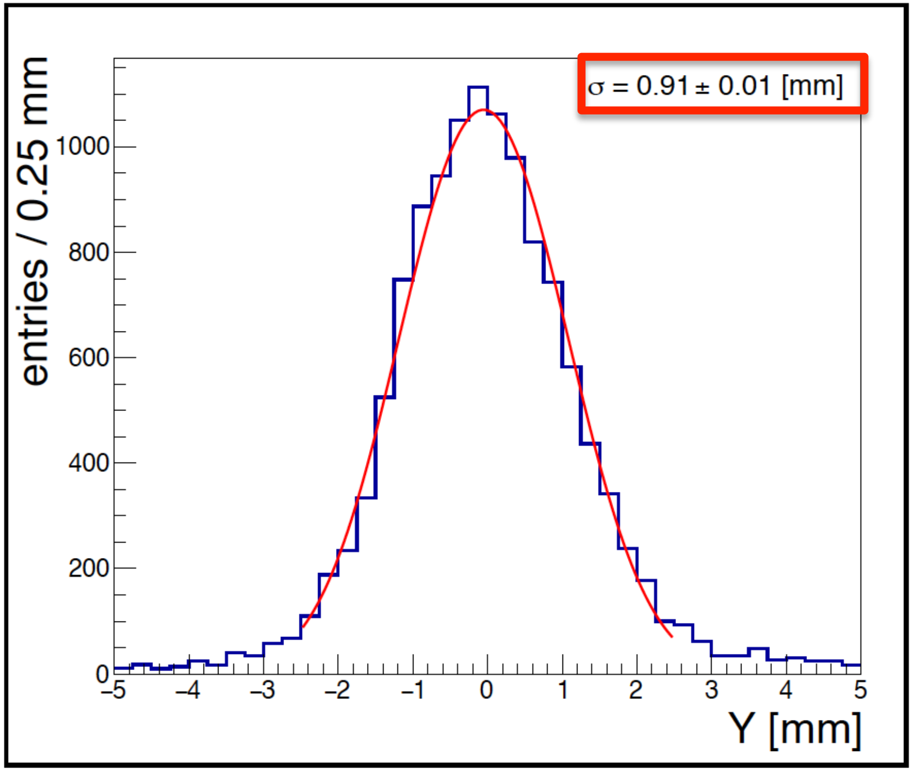
Position Resolution

- Electron beam spot is rather large : ~cm size
- We constrain the beam profile to a 2mm x 2mm square using a small scintillator trigger
- But still rather difficult to measure position resolution below the mm level.
- Ideally should use a reference tracking system with sub-mm precision, but was not available for our tests



Position Resolution

- Model the observed shower center position as a convolution of the square beam profile with a gaussian
- Fit to the data to extract the resolution (width of gaussian)

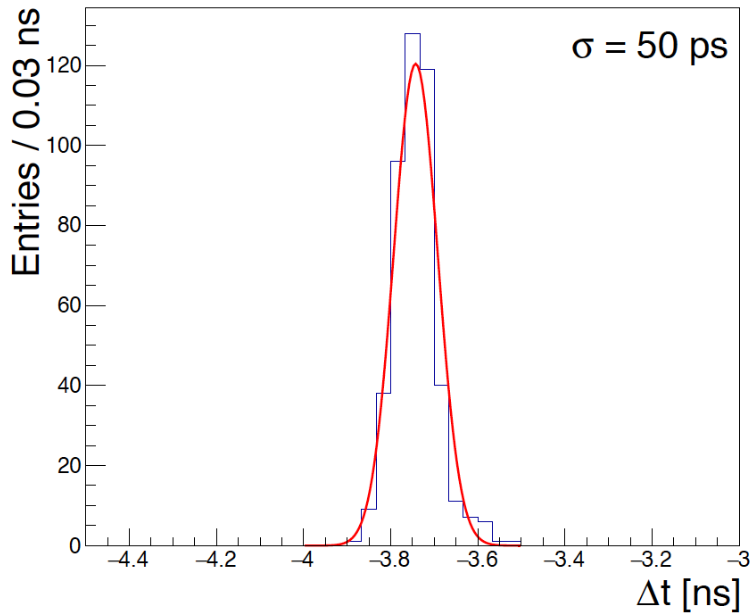


- Obtain position resolution just under 1mm.
- Recall that the pixel was a 6mm square

Time Resolution

- Time resolution can be measured with respect to a reference MCP detector (Photek 240)
  - Reference detector was independently measured to have resolution better than 10ps for EM showers
- Shower time-stamp reconstructed using simple charge / energy weighting

$$t = \frac{\sum_{i \in \mathrm{pixels}} Q_i t_i}{\sum_{i \in \mathrm{pixels}} Q_i}$$



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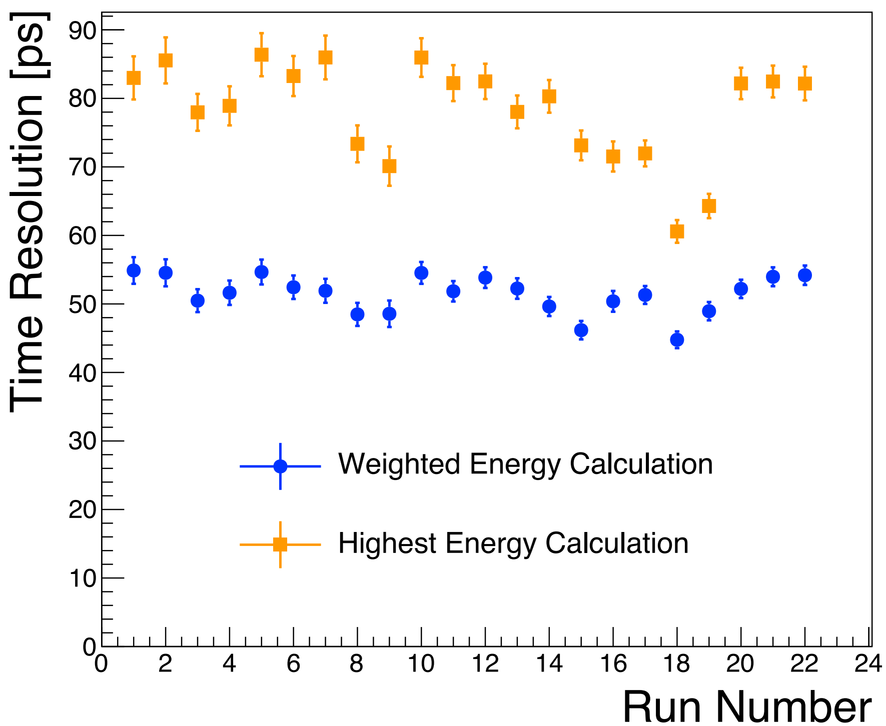
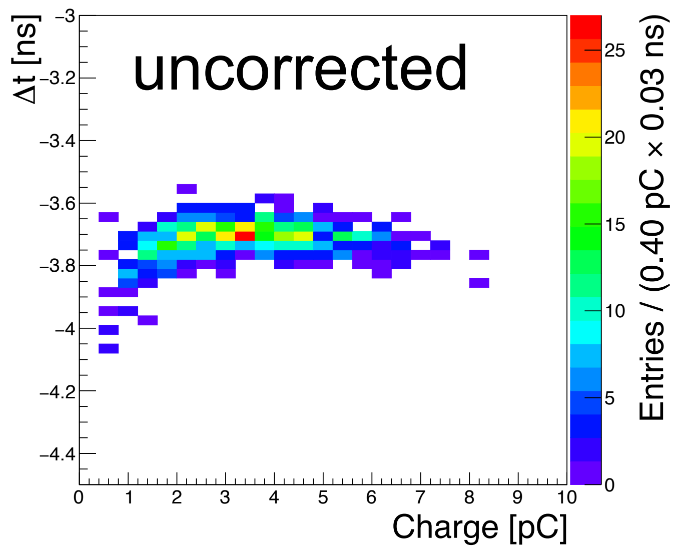
Time Resolution

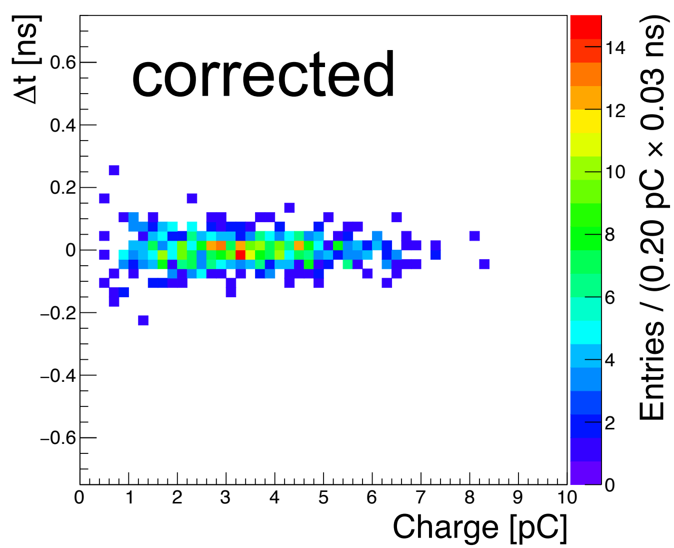
- Using the largest charge pixel yields time resolution ~80ps
- Using the energy-weighted time reconstruction yields resolution around 50ps
  - Similar to result we obtained when pixel channels are ganged together



Charge dependence of time measurement

- We observe some dependence of time stamp on the measured charge
- Calibrate this out, and see the impact on time resolution





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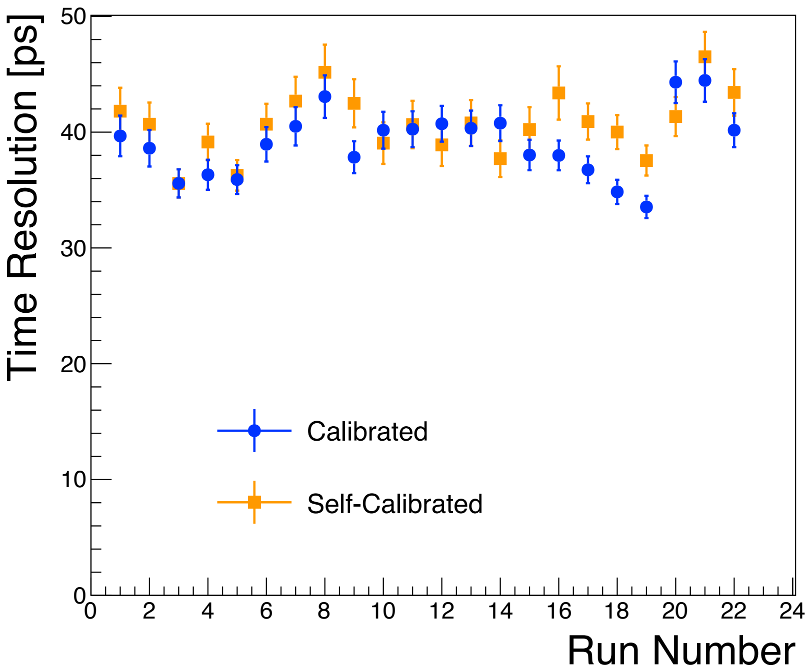

- After corrections in each pixel, we improve the time resolution to around 35-40ps

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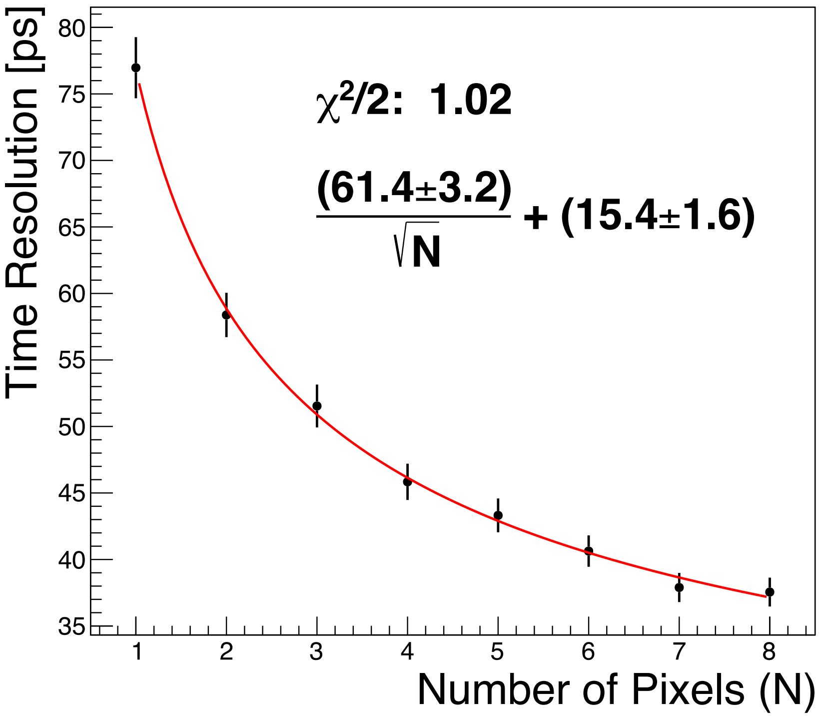
Time Resolution vs Number of Pixels



- Study time resolution as a function of how many pixels are included in the reconstruction
- Observe consistency with 1/sqrt(N) behavior

- additional information in transverse direction helps if there's still more information about the EM shower there

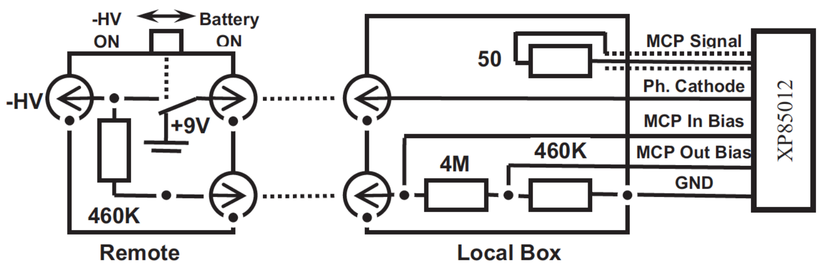
Summary

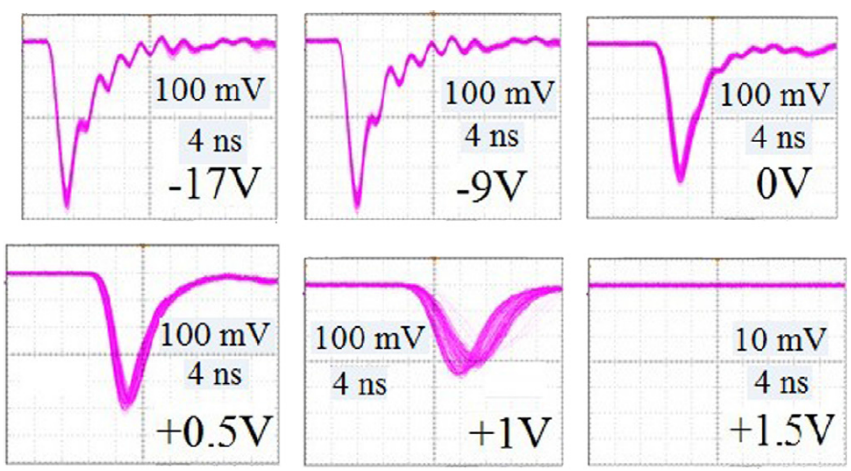
- Secondary emission calorimeters are important tools for future collider experiments
  - Radiation resistant & fast

- We studied important aspects of SEC's using an MCP-based prototype with electron beams:
  - Achieves near 100% efficiency for EM showers
  - Timing capability around 50ps & can be potentially improved to 35ps with more detailed calibrations
  - With coarse pixelated readout, achieved position resolution better than 1mm (1/6 of pixel size)

Backups

Apply a reverse bias voltage to the photocathode





- A +9 V battery used to apply a voltage across photocathode to prevent photo-electrons from entering MCP
- Laser measurements verify that above +1.5 V, no more photo-electron signals are made

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- Tungsten Moliere radius : 0.93cm
- Tungsten radiation length: 0.35cm